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The development of a tool for assessing the quality of closed circuit camera footage for use in forensic gait analysis

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ABSTRACT

Gait analysis from closed circuit camera footage is now commonly used as evidence in criminal trials. The biomechanical analysis of human gait is a well established science in both clinical and laboratory settings. However, closed circuit camera footage is rarely of the quality of that taken in the more controlled clinical and laboratory environments. The less than ideal quality of much of this footage for use in gait analysis is associated with a range of issues, the combination of which can often render the footage unsuitable for use in gait analysis. The aim of this piece of work was to develop a tool for assessing the suitability of closed circuit camera footage for the purpose of forensic gait analysis.

A Delphi technique was employed with a small sample of expert forensic gait analysis practitioners, to identify key quality elements of CCTV footage used in legal proceedings. Five elements of the footage were identified and then subdivided into 15 contributing sub-elements, each of which was scored using a 5-point Likert scale. A Microsoft Excel worksheet was developed to calculate automatically an overall score from the fifteen sub-element scores. Five expert witnesses experienced in using CCTV footage for gait analysis then trialled the prototype tool on current case footage. A repeatability study was also undertaken using standardized CCTV footage. The results showed the tool to be a simple and repeatable means of assessing the suitability of closed circuit camera footage for use in forensic gait analysis.

The inappropriate use of poor quality footage could lead to challenges to the practice of forensic gait analysis. All parties involved in criminal proceedings must therefore understand the fitness for purpose of any footage used. The development of this tool could offer a method of achieving this goal, and help to assure the continued role of forensic gait analysis as an aid to the identification process.

1. Introduction

Closed Circuit Television (CCTV) cameras are a common feature of twenty first century urban living. First developed as a means of observing rocket launches at close quarters,[1] CCTV cameras were initially investigated as a method of crime prevention in the UK in the 1970s and 1980s. During the late 1990's their use as a crime deterrent increased and now they can be seen above most high streets in the UK. As there are no regulations covering the registration of CCTV cameras, the number currently in operation in the UK is not known. Estimates vary considerably with McCahill and Norris (2002),[2] having suggested that there were 4.2 million cameras in the UK, while Gerrard and Thompson (2011)[3] later put the figure as being much lower at 1.85 million. These estimates are based on different methodologies, but share a heavy reliance on extrapolation. Whatever the true figure, CCTV is now an accepted part of daily life in the UK, and as such has become an accepted facet of criminal proceedings.

As is the case with CCTV camera installation and usage, there are no requirements or minimum standards with regard to the quality of the footage captured. The result is that although a great deal of information is recorded, it can often be of limited use in the identification of the perpetrators of crimes. This is particularly true of the use of CCTV footage in forensic gait analysis. In answer to a question at the Central Criminal Court in 2000, Kelly described forensic gait analysis as being "the identification of a person or persons by their gait or features of their gait, usually from CCTV footage and in comparison to footage of a known individual".[4] Gait is the pattern of movement utilized during locomotion, and as such key elements are its dynamic and repetitive nature. Different gait

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patterns will be used by a person to achieve different velocities. Gait is therefore a function not only of the person, but of their purpose. Gait is also influenced by external factors such as clothing, the carrying of objects and the ground surface and internal factors including mood, mechanical and neurological pathologies and anatomy.[5–10] CCTV footage has the potential to capture the kinematic detail of the gait of a person, and therefore contribute to their identification. The identification in this case is comparative, that is to say a recording of a known person is compared to that of a suspect. The outcome is a judgement made by someone, often a healthcare or human science professional, with experience in the analysis of human gait. The role of experienced gait analysts in criminal proceedings is supported by the findings of Birch et al. (2013).[11] The findings of this study provide evidence that individuals with experience in visual gait analysis are consistently able to identify individuals by their gait.

In order to allow a credible judgement to be made the CCTV footage needs to provide sufficient and appropriate data. The quality and nature of CCTV footage submitted for the purpose of identification is variable in many ways, to the extent that in some cases the judgements made on the basis of the footage may be open to challenge. Factors affecting the recording in this way include the frame rate, the positioning of the camera relative to the subject, the ambient lighting and type of clothing being worn by the subject, any of which could render footage unsuitable for the purpose of forensic gait analysis.[12] During criminal proceedings any CCTV footage may be considered by a range of people with a greater or lesser understanding of the effects of such factors on the validity of the conclusions that could be drawn from it.

The purpose of this work was to develop a simple tool for the assessment of CCTV footage for use in forensic gait analysis. The tool should be suitable for use by anyone involved in criminal proceedings and not be reliant upon expertise in either gait analysis or CCTV surveillance.

2. Method and outcomes

A Delphi strategy[13] was employed to reach a consensus amongst experts in this field as to the key factors affecting the appropriateness of CCTV footage for use in forensic gait analysis. The Delphi strategy, originally developed as an interactive method of forecasting, uses a panel of experts to answer questions or give judgements in a series of developmental rounds. After each round the outcomes are summarized and used to inform subsequent rounds, the experts progressively modifying their feedback as they feel appropriate, until a consensus is reached.[14,15] Three practitioners with considerable experience of analysing CCTV footage for the purposes of forensic gait analysis were selected and contacted. While this number is low for a Delphi study,[16] the area of practice concerned is highly specialized, and the number of practitioners known to be operating in the field at the time was small (six). All three participants were podiatrists qualified at post graduate level, registered with the Health and Care Professions Council and trained in observational gait analysis. Each had a minimum of 20 years professional experience and 10 years involvement with forensic gait analysis. The participants were asked to state what they considered to be significant factors that affected the quality of the footage they had been presented with during their career, in terms of its appropriateness for use in forensic gait analysis.

The outcomes of the first round of the exercise were summarized and reported to the practitioners. The consensus was that there were four key factors: the quality of the picture produced, the lighting, the direction the footage was taken from relative to the subject, and the subject being recorded. Following the second round a further factor of frame rate was added to produce a total of five key factors. Based on the comments of the practitioners each of the key factors was assigned a number of contributing sub factors, as shown in Table 1.

Table 1
Key factors and sub factors of CCTV footage identified by practitioners.

Key factor	Sub factors
Picture	• sharpness • contrast • brightness
Lighting	• quality of lighting • shadow interference • reflection interference • direction of light source
Direction	• side/front • below/above
Frame Rate	• continuous flow of movement/series of still images
Subject	• upper body in shot • lower body in shot • speed of movement • number of steps captured • clothing

The language used to describe the factors and sub factors was carefully selected to ensure that it could be understood by any person involved in criminal proceedings, not just those with professional experience of CCTV footage. Care was taken to ensure that the sub factors could be assessed solely by viewing the footage, and that the assessment did not require access to technical specifications. The factors shown in Table 1 were transferred into a Microsoft Excel workbook. Each of the fifteen sub factors was allocated a five point Likert scale using simple descriptors, for example 'very good contrast' to 'very poor contrast', and each point on the scale allocated a score from minus 2 to plus 2. Positive scores represented qualities that were considered to be advantageous in terms of the appropriateness of footage for forensic gait analysis, while negative scores represented those that were considered disadvantageous. In the cases of eleven of the sub factors, the Likert scale represented at one end the most advantageous quality and at the other the most disadvantageous (maximum 2, minimum −2). In the cases of three of the sub factors (brightness, below/above and speed of movement) both ends of the scale represented disadvantageous qualities, and the central point an advantageous quality (maximum 2, minimum 0). In the case of the remaining sub factor (side/front) both ends of the scale represented advantageous qualities, and the central point a disadvantageous quality (maximum 2, minimum 0). This weighting was arrived at from the experience of the experts who considered that in the case of these four sub factors the disadvantages nature of the characteristic of the footage was likely to have less of an impact on the overall usability of the footage than was the case of the other eleven sub factors.

Active buttons were added to each point on the Likert scales, allowing the user to simply click on the desired point to produce a score for each sub factor, which were automatically summated to produce a subtotal for each key factor, and an overall score for all key factors. The maximum possible overall score was 30, the minimum −22. This range was divided into five bands, A to E, as shown in Table 2. Bands were assigned to the overall scores to facilitate easy interpretation of the outcomes. A banding system

Table 2
Score ranges and associated bands.

Score range	Band assigned
30 to 21	A
20 to10	B
9 to −1	C
−2 to −12	D
−13 to −22	E

Table 3
Coefficients of variation (CV% = $(SD/\overline{\chi})100$) produced by repeat evaluations of footage.

Expert practitioner	Coefficient of variation (%)
1	2.25
2	5.08
3	0.00
4	2.53
5	0.00
Overall CV	5.01
Mean CV	1.97

was employed for two reasons. Firstly, it rendered the outcomes into a ranked form familiar to users from a variety of educational and experiential backgrounds, banding commonly being used for purposes as diverse as school assessments and council tax charges. Secondly, the banding strategy accommodated the majority of small variations in outcome, which was considered advantageous in terms of conveying a simple message to the inexperienced user and allowing easy comparisons to be made between different pieces of footage.

At this stage the individual sub factor scores, key factor scores and overall score were all visible to the user, allowing subsequent evaluation to be undertaken by the practitioners.

The completed Microsoft Excel workbook, with embedded macros, was circulated by email to the original three practitioners, plus an additional two expert practitioners, for a further round of consultations. All practitioners were asked to trial the tool on CCTV footage in their own current forensic gait analysis casework. This third round of consultations produced positive comments from all five practitioners with regards to the ease of use of the tool, despite two of the practitioners experiencing initial difficulties in enabling the Excel macros on their computers. A simple set of user instructions resolved this issue. The practitioners expressed differing opinions with regard to the potential weighting of key and sub factors, resulting in no changes to the weightings being applied to the tool. It was agreed by the participants that the tool was fit for purpose, and yielded repeatable results when applied to the same footage on different occasions.

A repeatability trial of the tool was subsequently undertaken. The five expert practitioners were asked to perform a series of five evaluations on a single piece of CCTV footage, undertaken over a period of one week, one evaluation per day. The coefficients of variation (CV% = $(SD/\overline{\chi})100$) for each practitioner and overall are shown in Table 3. These show an overall coefficient of variation of 5.01% (mean score = 35.56, max score = 38, min score = 33) and a mean coefficient of variation of the individual practitioners results of 1.97%. All assessments undertaken by all practitioners yielded a banding result of 'B'. These results suggest a good level of repeatability, particularly in terms of the final quality banding of the footage that was being assessed.

The tool was then made available for trial use to expert practitioners of forensic podiatry, together with a request for comments on ease of use and effectiveness. To date practitioners have reported the tool to be easy to use and effective in providing an overall and easily understandable means of assessing the quality of CCTV footage.

3. Conclusions

In view of the numbers of CCTV cameras currently in operation, the use of recorded footage in criminal proceedings is likely to increase. Its use in forensic gait analysis is also therefore likely to increase. While practitioners are making every effort to ensure that their judgements on comparative gait analysis are well founded, the lack of both an evidence base and quality assurance processes for this area of forensic practice could be problematic leaving practice potentially open to challenge. The purpose of this piece of work was to develop a simple tool for the assessment of CCTV footage for use in forensic gait analysis, and in doing so contribute to the enhancement of practice. The tool produced was shown to be easy to use and understand, and as such suitable for use by anyone involved in such criminal matters. The results of the Delphi study, together with those of the repeatability test suggest a good face validity of the tool. Development work will continue, particular attention being paid to intra and inter tester reliability and the weighting of the component sub factors.

The tool provides a means for CCTV footage being used in forensic gait analysis to be assessed for viability, providing a context for any judgements made on the content of the footage. The tool also offers a simple means of assessing footage at source, allowing unsuitable footage to be dismissed without the need for the time consuming and potentially expensive processes of expert consultation.

References

1. Dornberger W. *V-2*. New York: Ballantine Books; 1954.
2. McCahill M, Norris C. Estimating the extent, sophistication and legality of CCTV in London. In: Gill M, editor. *CCTV*. Leicester: Perpetuity Press; 2003. p. 51–66.
3. Gerrard G, Thompson R. Two million cameras in the UK. *CCTV Image* 2011;**42**: 10–2.
4. Kelly H. *Central criminal court*. London: R v Saunders; 2000.
5. Crosbie J, Flynn W, Rutter L. Effect of side load carriage on the kinematics of gait. *Gait and Posture* 1994;**2**(2):103–8.
6. Qu X, Yeo CJ. Effects of load carriage and fatigue on gait characteristics. *Journal of Biomechanics* 2011;**44**(7):1259–63.
7. Thies SB, Richardson JK, Ashton-Miller JA. Effects of surface irregularity and lighting on step variability during gait: a study in healthy young and older women. *Gait and Posture* 2005;**22**(1):26–31.
8. Menant JC, Steele JR, Menz HB, Munro BJ, Lord SR. Effects of walking surfaces and footwear on temporo-spatial gait parameters in young and older people. *Gait and Posture* 2009;**29**(3):392–7.
9. Heiden TL, Sanderson DJ, Inglis JT, Siegmund GP. Adaptations to normal human gait on potentially slippery surfaces: the effects of awareness and prior slip experience. *Gait and Posture* 2006;**24**(2):237–46.
10. Gross MM, Crane EA, Fredrickson BL. Effort-Shape and kinematic assessment of bodily expression of emotion during gait. *Human Movement Science* 2012;**31**(1):202–21.
11. Birch I, Ray L, Christou A, Fernando M, Harrison N, Paul F. The reliability of suspect recognition based on gait analysis from CCTV footage. *Science and Justice* 2013;**53**(3):339–42.
12. Di Maggio DA, Vernon W. *Forensic podiatry: principles and methods*. New York: Human Press; 2011.
13. Green K, Armstrong JS, Graefe AA. Methods to elicit forecasts from groups: Delphi and prediction markets compared. *Foresight: The International Journal of Applied Forecasting* 2007;**8**:17–20.
14. Linstone HA, Turoff M. *The Delphi method: techniques and applications*. Reading, Mass: Addison-Wesley; 1975.
15. Okoli C, Pawlowski SD. The Delphi method as a research tool: an example, design considerations and applications. *Information & Management* 2004;**42**(1):15–29.
16. Vernon W. The Delphi technique: a review. *International Journal of Therapy and Rehabilitation* 2009;**16**(2):69–76.